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The Investigation of a Gasoline Automobile Lighting and Starting Set

Electrical Engineering

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THE INVESTIGATION OF A GASOLINE AUTOMOBILE LIGHTING AND STARTING SET

BY

JAMES DOUGLASS SHEPPERD

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

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June 1, 1914

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

James Douglass Sherperd

ENTITLED The Investigation of a Gasoline Automobile Lighting and Starting Set.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Bachelor of Science in Electrical Engineering

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I. INTRODUCTION.

Electricity may be said to have four applications to the gasoline automobile. These include ignition, lighting, starting and gear shifting. The first application is fundamental to the production of a spark for ignition. At first this spark was produced by a few dry batteries together with a spark coil, interrupter and distributor. Later the magneto came into use. One of the most standard forms today is a high tension magneto, which consists of a small A. C. generator with a permanent magnet field and a secondary winding on the armature, stepping up the voltage for producing a spark.

The second use of electricity on automobiles is for lighting. Users of motor cars early saw the convenience and advantage of electric lights as compared with the old oil or gas lighting equipment. Some at first attempted to light machines from dry cells; but the low capacity of these was unfavorable. Then the storage battery was tried with much success. However, the necessity and inconvenience of frequent charging prevented the wide-spread use and so it did not become a serious competitor of the acetylene lighting system, until the small generator was adapted to the automobile. There are three general methods of use; first, the generator supplies energy directly to the lamps; second, the generator charges a storage battery, from which the lights operate; third, the generator and battery supply energy in parallel. This last system is superior to the

others, especially since at high speeds thegenerator may be not only supplying all the lighting, but may also be charging the battery. Another advantage lies in the fact that the storage battery will maintain a higher terminal voltage if it has charging current flowing in while it is being used. Some makers also have the ignition furnished by the generator instead of supplying an extra magneto.

The third use of electricity has been that of starting. Hand cranking has long been a source of much annoyance.. About ten years ago automobile engineers began devising the gas starters, by which a charge of acetylene was admitted to the top of a piston and ignited, thus starting the cycle. This system wa. successful but not economical, and disastrous accidents to the engine occurred several times,,blowing off the cylinder head. So when electric lighting came into use, the electric starter was a natural consequence. A small electric motor was very suitable for turning the engine, since the energy could easily be obtained from the battery.

In the development of lighting and starting equipment some makers have combined both into a single unit, while others have made the generator and the motor two separate machines. Recently it has been found that difficulties of design and concentrated weight have against the single unit type and now the two unit type is looked upon more favorably. They have been designed to operate on from six to twenty-four volts; more recently engeers have been trying

to set a six volt standard. This is partly due to the fact that the six volt lamps are more satisfactory, due to having a stronger filament than the twentyfour volt lamps, and also the larger set requiring parallel charging. In the methods of installing these sets there have been wide differences. Some builders transmit the power from the motor to the engine at the fly wheel, some at the front of engine through the timing gear, others connect the starting motor to the transmission. The generators may or may not have similar positions.

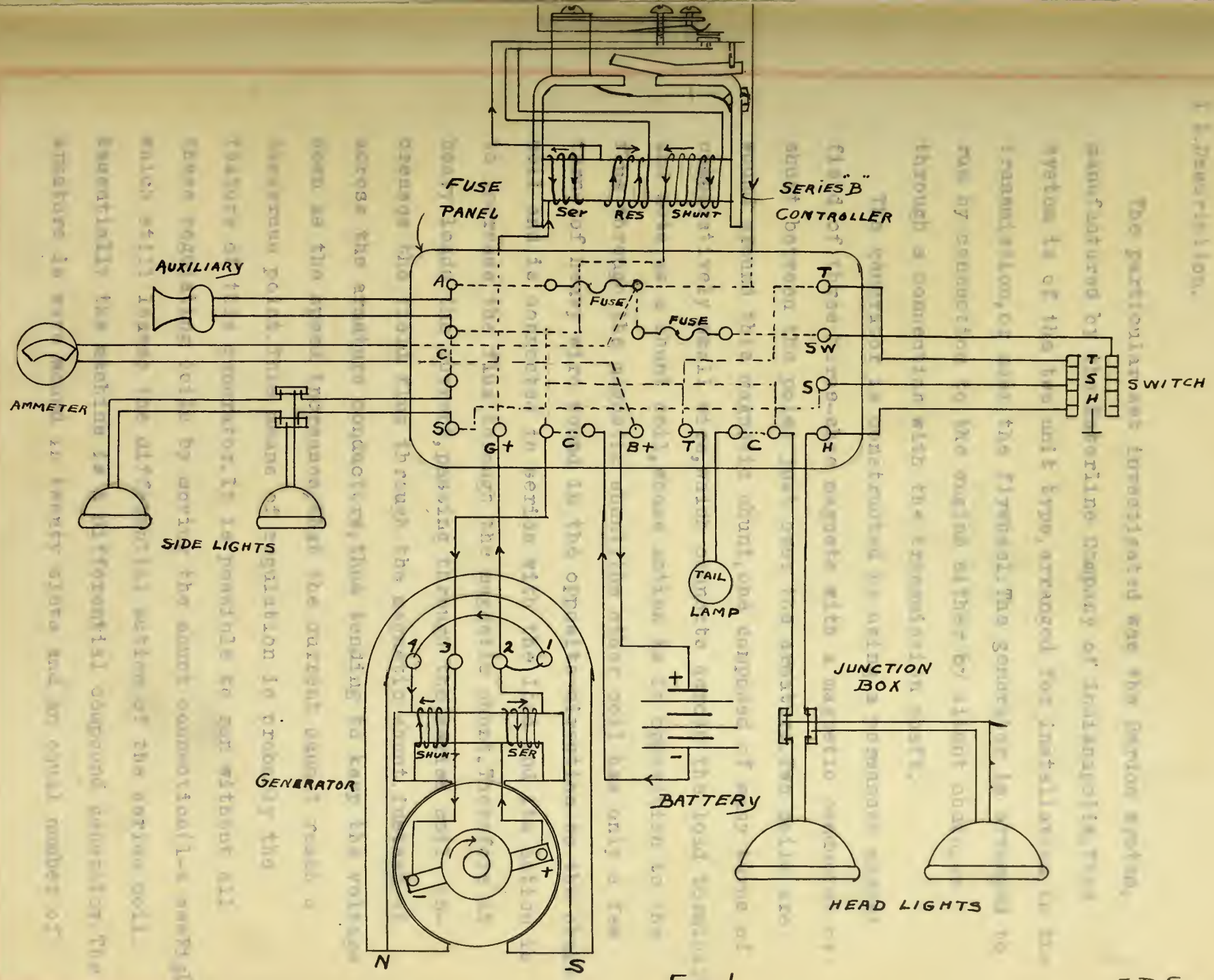


Fig. 1.

J.D.S 5-7-14

Fig. 1.

T.D.S. 2-1-14

I I.Description.

The particular set investigated was the Berdon system, manufactured by the Esterline Company of Indianapolis.This system is of the two unit type,arranged for installation in the transmission,or near the flywheel.The generator is arranged to run by connection to the engine either by silent chain,or through a connection with the transmission shaft.

The generator is constructed by using a permanent magnet field of three horse-shoe magnets with a magnetic conductor or shunt between the poles just over the armature.Two coils are wound around this magnetic shunt,one composed of many turns of comparatively small wire,which connects across the load terminals and acts as a shunt coil,whose action is in opposition to the flux through the magnetic shunt;the other coil has only a few turns of heavy wire wound in the opposite direction to the shunt coil and is connected in series with the load and its action is to increase the flux through the magnetic shunt.Therefore at heavy loads the current,passing through the series coil increases the field flux through the magnetic shunt.instead of across the armature conductors,thus tending to keep the voltage down as the speed increases,that the current cannot reach a dangerous point.This means of regulation is probably the feature of this generator.It is possible to run without all these regulating coils by moving the shunt connection(1-4 seeFig) which still leaves the differential action of the series coil. Essentially the machine is a differential compound generator.The armature is wave wound in twenty slots and an equal number of

commutator bars and two carbon brushes. The diameter of the armature is three inches wnd the length four and one half inches. The end frame work was of aluminum with ball bearings for the shaft. The machine is seven and three-fourth inches high, nine inches long and four and three-fourth inches wide.

The generator supplies all the load through a fuse panel and a controller which can be seen in the drawing of the generator and equipment, (Fig. 1). The current from the generator passes through the coils on the controller but cannot complete the load circuit until the arm at the top has pulled down and made connection. This arm will pull down by magnetic action when the current through the controller coils has reached such a value as is suitable for charging the battery. This is of course when the machine is running fast enough so that the terminal voltage is at least equal to or slightly greater than the battery voltage. The connections are made in such a way that the battery will be in circuit with the generator at all times when the controller lever is closed, while the other equipment is turned on at will by the switch and will be supplied either from the battery or the generator or the two in parallel. This may be more easily seen from the following simple diagram, Fig. II.

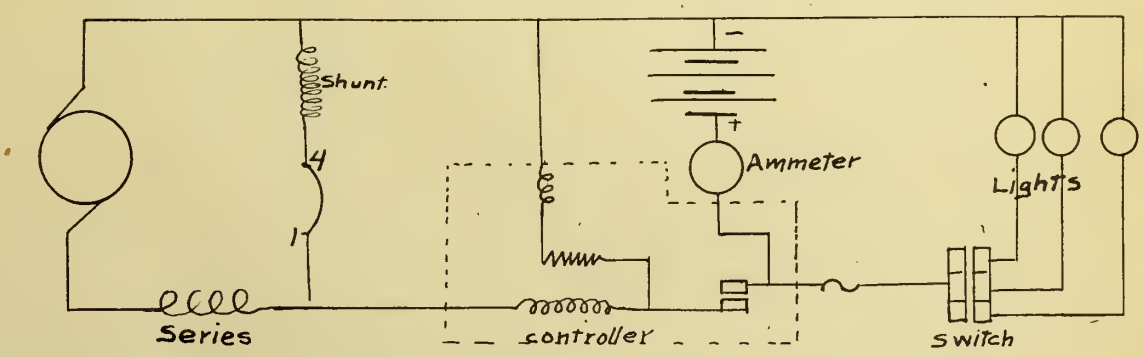


Fig. II

The motor as constructed has a laminated magnet casing with no joints in the magnetic circuit except for the air gap. It is a two pole series machine with the field coils divided into two parts, so that the path of the current was through one side of the field to the armature, through the armature to the other side of the field, and out at the terminal. This is shown in the following diagram, Fig. 3.

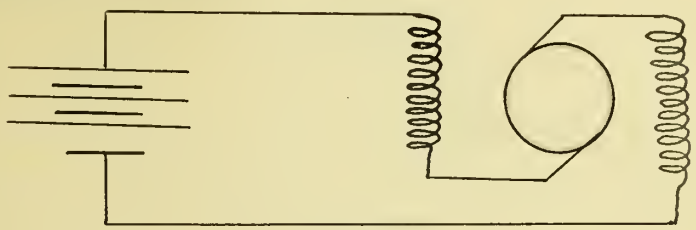


Fig. 3

The armature is wave wound in ninteen slots with an equal number of commutator segments. The shaft is supported in ball bearings, set in aluminum end frame and would be connected to the engine probably at the flywheel through a set of planetary reduction gears and an over running clutch which will give a reduction ratio of from 20 or 30 to 1, depending on the size of the engine. The width is four and one-fourth inches, height seven and one-eighth inches and the weight 25 pounds. The motor operates directly on the battery without going through the controller or fuse panel.

III.

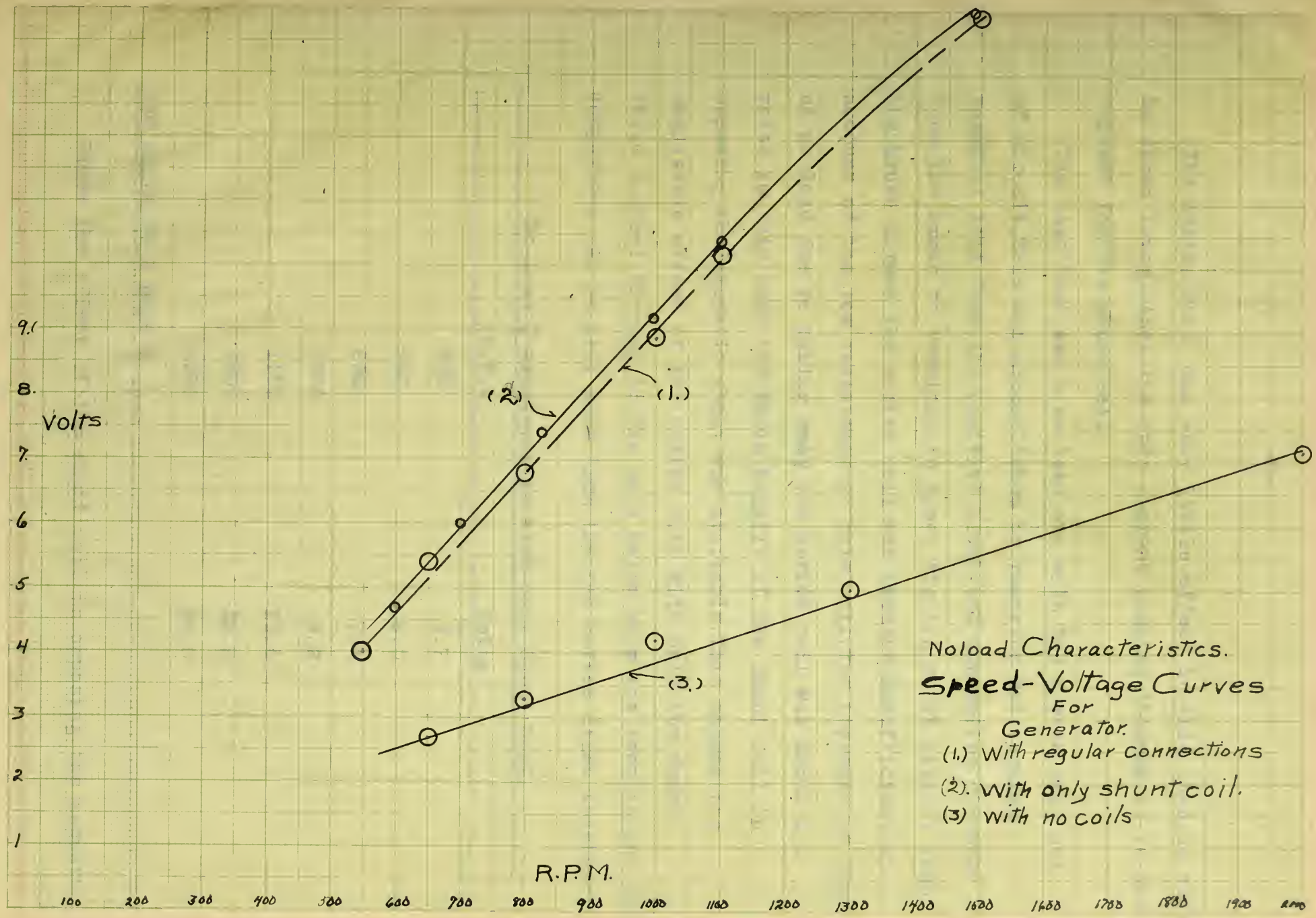
Tests.

The following is a description of the complete test. While running the tests on the generator, it was belted to a small electric motor, whose speed could be varied at will. The generator and driving motor were both fastened on a single long board to keep the running conditions the same at all times as regards the tension in the belt.

Generator.

The first test was run at no load with connections made as in ordinary running. The voltage varied directly with the speed giving almost a straight line when the curve was drawn. The usual minimum battery charging voltage coming at about 750 revolutions per minute of the generator and increasing almost one volt for each additional 100 revolutions per minute. This is more easily seen from the following data which was taken and the accompaning curve. See curve No 1, page 8.

Speed in R.P.M.	Voltage.
550	4
650	5.4
800	6.8
1000	8.9
1100	10.2
1500	13.9
2000	19.00
2500	24.00



Noload Characteristics.

Speed-Voltage Curves

For

Generator.

(1.) With regular connections

(2). With only shunt coil.

(3) With no coils

The series coil has very little effect in this case as will be shown later, since the only current passing through it is the current for the shunt coil.

The next test was a no load one with the series coil out of circuit. This was accomplished by removing the regular terminal lead from the positive brush and connecting directly from the brush to terminal No 4, see Fig 1. A short circuit from the brush across the series coil was thought insufficient on account of the low resistance of this coil. The increase of flux at no load due to taking away the series coil was about 0.3 volts. In this case the whole benefit of the shunt coil in opposing the magnetic shunt was available. This showed the negligible effect of the series coil with only the shunt field current through it. The data below show the results and the comparison can be best seen from the two curves drawn together.

No load Characteristic with only Shunt Coil.

R.P.M.	Volts
600	4.7
700	6.0
830	7.4
1000	9.2
1100	10.4
1500	13.9
2000	19.0

See curve No 2 page 8.

Since the effect of the shunt coil in opposing the magnetic

shunt was to increase the flux passing across the armature conductors, to get the full effect of the shunt coil the generator was run at no load with no coils connected in. This shows the much lower voltage due to the by-pass of the flux. The effect of the shunt coil was seen to be just slightly greater than that of the magnetic shunt, so that in running with the regular connection the shunt coil not only couteracts the magnetic shunt but send some additional flux out of the pole faces. The data show very plainly the strong diversion of flux caused by the magnetic shunt.

No load characteristic with no Coils.

R.P.M.	Volts.
650	2.7
800	3.3
1000	4.2
1300	5.0
1500	5.8
2000	7.2
2300	8.5
2400	9.0

See curve No 3, page 8.

As series of tests were next made with a load on the generator. The tests were made with constant resistance and varying speed from about 600R.P.M. to a maximum of 2500 R.P.M. This corresponded to what would be a range of speed of from one-fourth to somewhat greater than normal speed. The first of

these was a run of only the shunt coil in operation to show the operation without the regulation.The voltage and current varied almost directly with the speed and increased rapidly as the speed increased.See curve 4,page 12. By leaving out the shunt coil and letting the current pass through the series coil alone a few values of current,voltage, and speed were found with the same resistance load.For the same voltage about four times the speed was required,since the series coil helped the by-pass of flux.

Load Curves With Constant Load. Shunt Coil Only.

R.P.M.	Volts	Amperes.
610	3.7	2.4
800	5.1	3.4
890	6.1	4.0
1050	7.5	4.9
1300	9.1	5.9
1500	10.6	6.9
1800	12.5	8.05
2000	13.4	8.6
2500	16.0	10.0

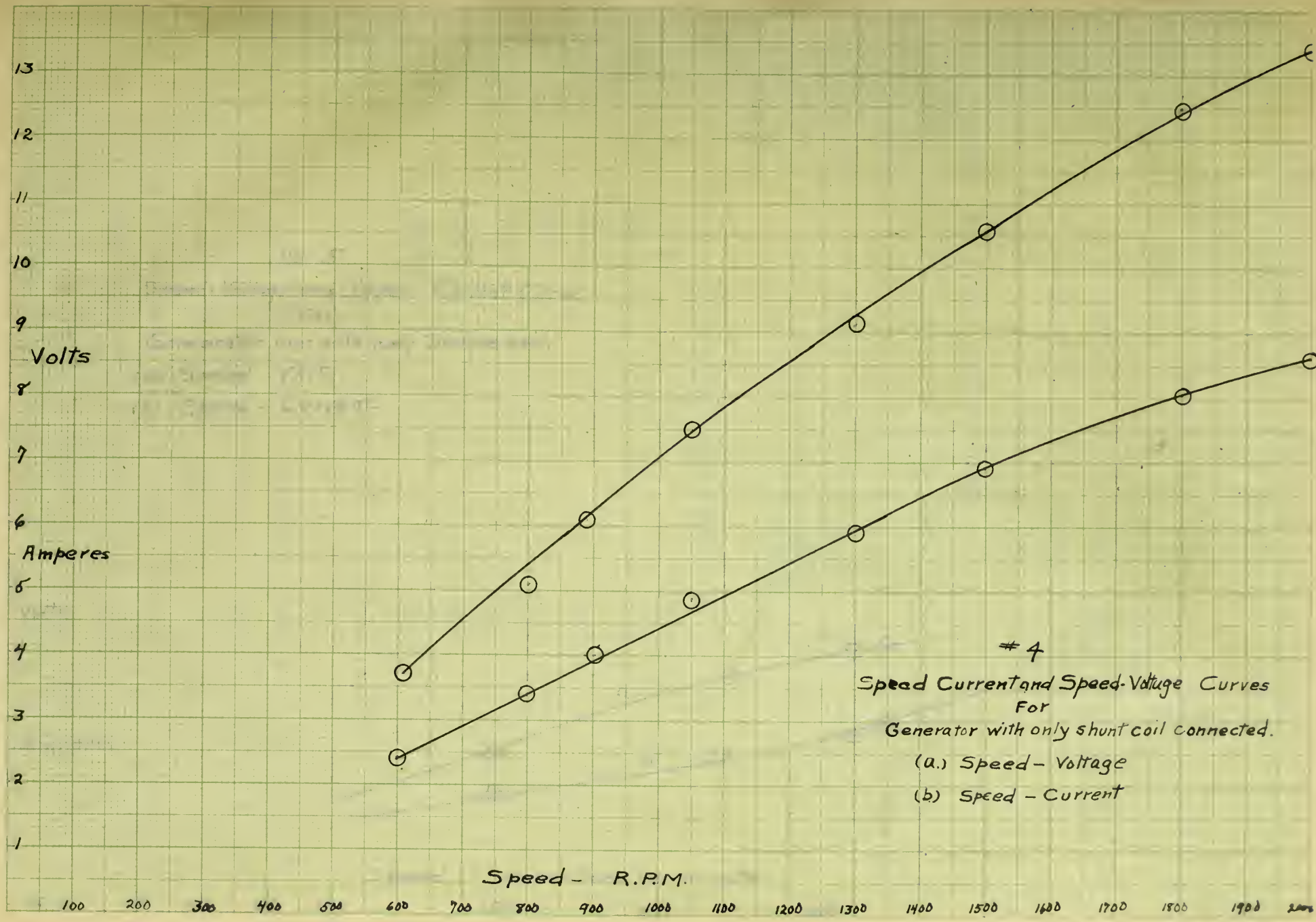
See curve No4,page 12.

Load Curve With Constant Load. Series Coil Only.

R.P.M.	Volts	Amperes.
1500	2.5	1.9
2210	3.7	2.5
2600	4.1	2.8
2700	4.2	2.95

See curve No 5,page 13.

A test was then run with neither coil connected in the circuit,taking the load directly from the brush terminals and opening the coil circuit.In this way,since a great deal of the



#4

Speed Current and Speed-Voltage Curves
For
Generator with only shunt coil connected.

(a.) Speed – Voltage

(b) Speed – Current

No. 5

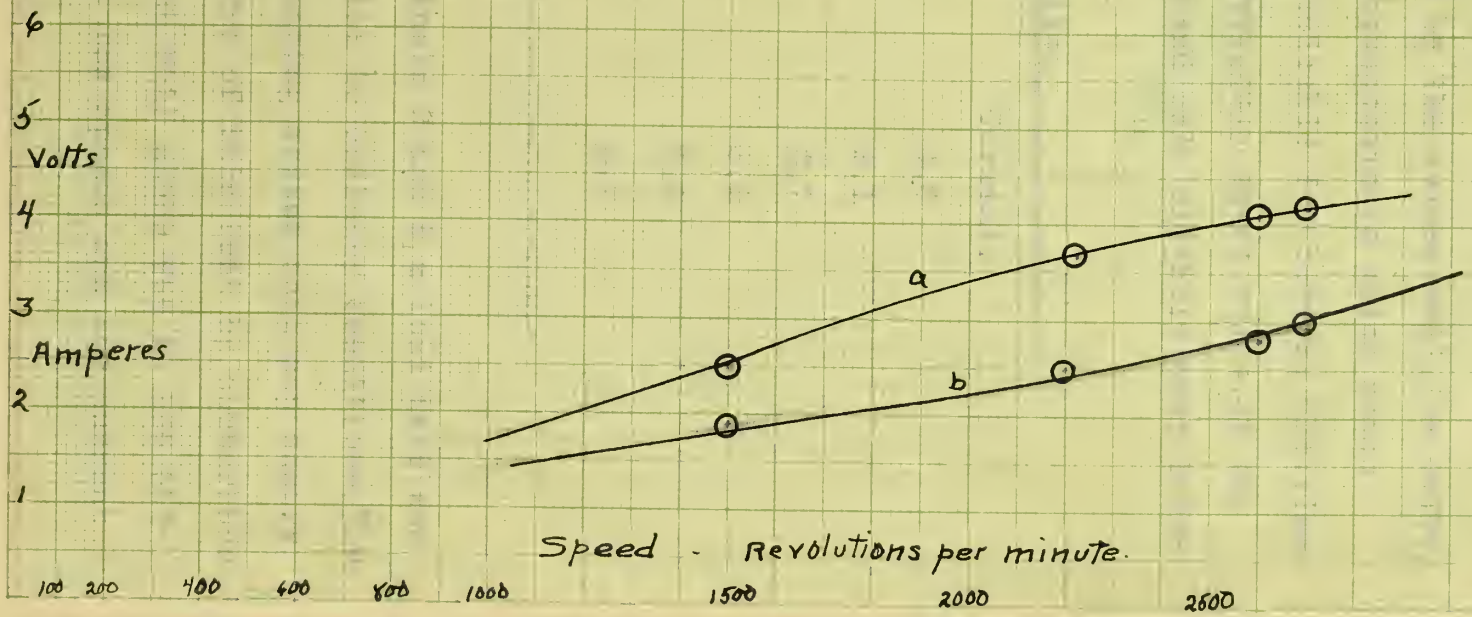
Speed - Voltage and Speed - Current Curve

For

Generator run with only Series coil.

(a) Speed - Volts

(b) Speed - Current.



flux passed through the magnetic shunt, high values of current and voltage were not obtainable even at maximum speeds. This would not be suitable as an operating condition, since current for battery charging would be obtainable only at high car speeds. It shows very well, however, the regulating effect of this magnetic shunt, when not assisted by the series coil. The curve, (No 6, page 15), shows the flat characteristic which would result and which would be very desirable for battery charging. The actual data taken show, however, only seven volts at the extreme high speed of 2000 R.P.M, and only slightly over three amperes.

Load Curve No Coils.

R.P.M.	Volts	Current.
950	3.5	1.6
1250	4.7	2.1
1600	6.0	2.7
1950	7.0	3.2
2180	7.65	3.5
2300	8.0	3.7

Now with connections at terminals 2 and 3, a load test was run which would be somewhat similar to ordinary conditions. The effect and operation of the regulating series coil can easily be seen from the data and the curve of this test by comparison with the data taken when the shunt coil alone was in the circuit, (curve No 7, page 16). Thus at low speeds and low current

No. 6

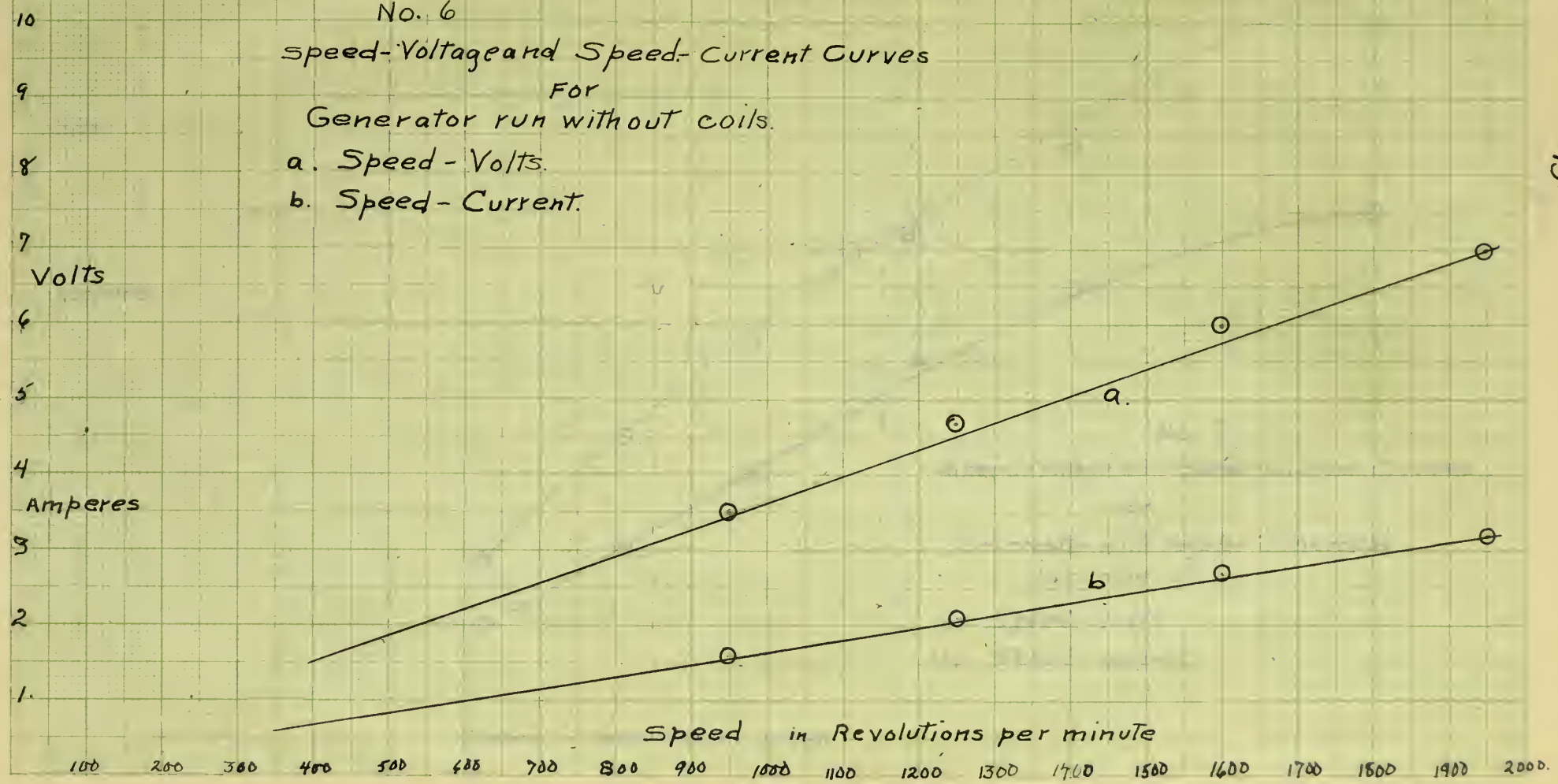
Speed-Voltage and Speed-Current Curves

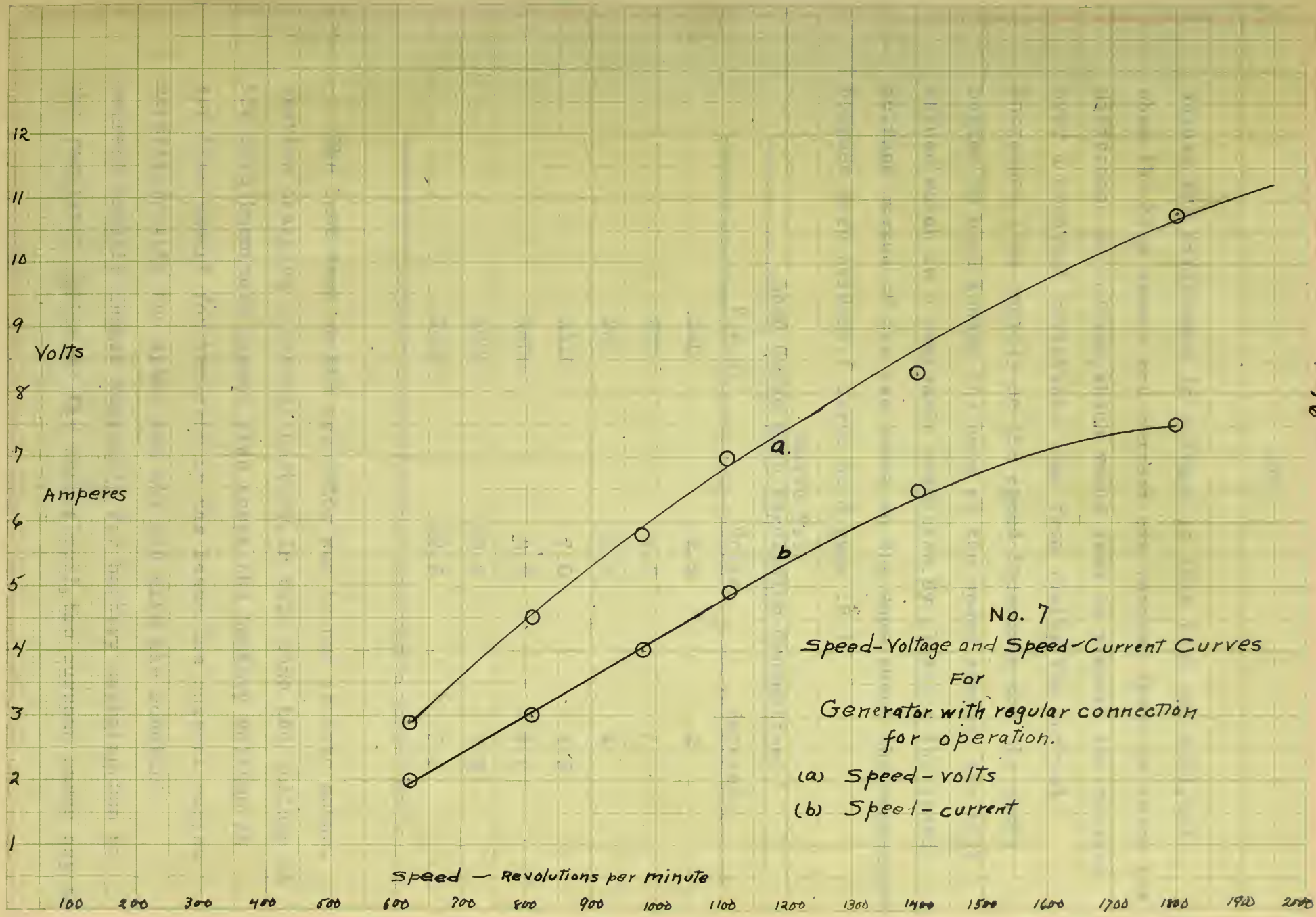
For

Generator run without coils.

a. Speed - Volts.

b. Speed - Current.





No. 7

Speed-Voltage and Speed-Current Curves

For

Generator with regular connection for operation.

(a) Speed - volts

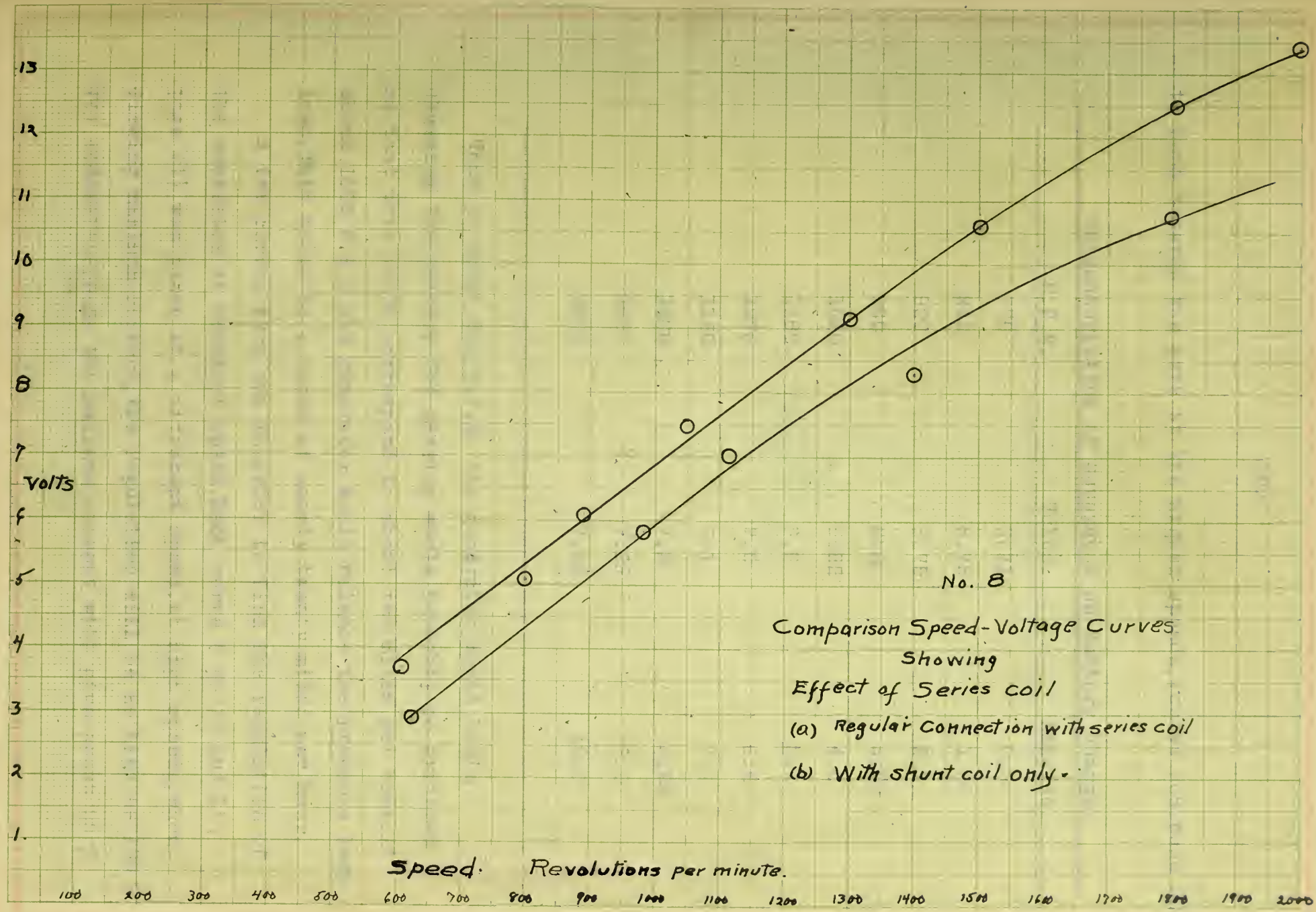
(b) Speed - current

values the difference in voltage is less than one volt, but when the high speeds and current are reached there is twice the difference in voltage, which would tend to prevent the current over a constant resistance load from rising. The current increases less rapidly as the speed increases and the curve begins to bend toward the axis as the speed reaches the high values which is a desirable condition. By plotting the speed voltage curves of the two tests on the same sheet the comparison becomes more evident, (curve No 8, page 18).

Curve Vll.
Load Curve with Regulation Connection.

R.P.M.	Volts	Amperes.
620	2.9	2
810	4.5	3
980	5.8	4
1110	7.0	4.9
1400	8.3	6.5
1800	10.8	7.5
2180	12.3	8.5

The last test on the generator was to put it into actual service charging a storage battery. In this case the voltage at the load terminals cannot rise above the battery voltage at any time except for the drop in the leads. The current varied materially with the speed and did not give the constant current usually deemed desirable for battery charging. Due to the regulator action of the series coil, the current curve begins



No. 8

Comparison Speed-Voltage Curves
Showing
Effect of Series coil
(a) Regular Connection with series coil
(b) With shunt coil only.

Fig. 6.

Comparison Open-Circuit Curves

(a) Primary coil only.

(b) Primary connected with secondary coil

Ballast 6 Ohms coil

Primary

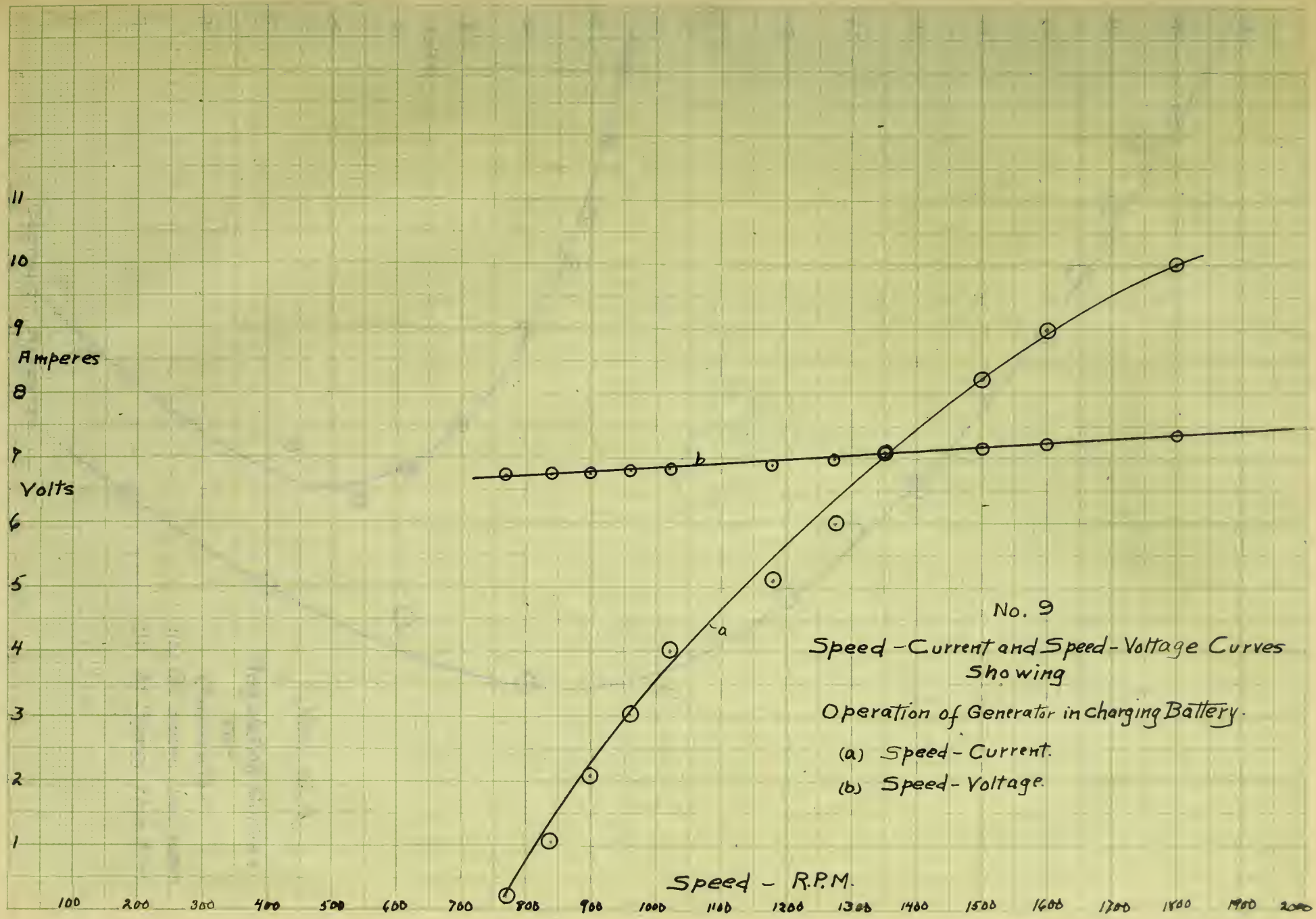
to bend towards the axis at the higher speeds, (curve No9, page 20)

Characteristics of Generator on Battery Charge.

R.P.M.	Volts.	Amperes.
770	6.71	0.2
840	6.73	1.05
900	6.75	2.1
960	6.8	3.05
1020	6.82	4.0
1180	6.9	5.1
1275	7.0	6.0
1350	7.1	7.1
1500	7.2	8.25
1600	7.28	9.0
1800	7.38	10.0

Thus at about 800 R.P.M. the generator would begin charging the battery. The gearing would probably be arranged so that this would correspond to about ten miles per hour. At about 1300 R.P.M the generator would balance the probable lamp load. This would be a speed of nearly twenty miled per hour.

A few curves were run in order to find the regulation of the generator at constant speed. Each curve (No 10 and 11 page 21) was taken at a different speed. At high speeds, when drawing maximum current, the regulation will be as high as 100 %. For moderate speeds the maximum current will give about 50 %



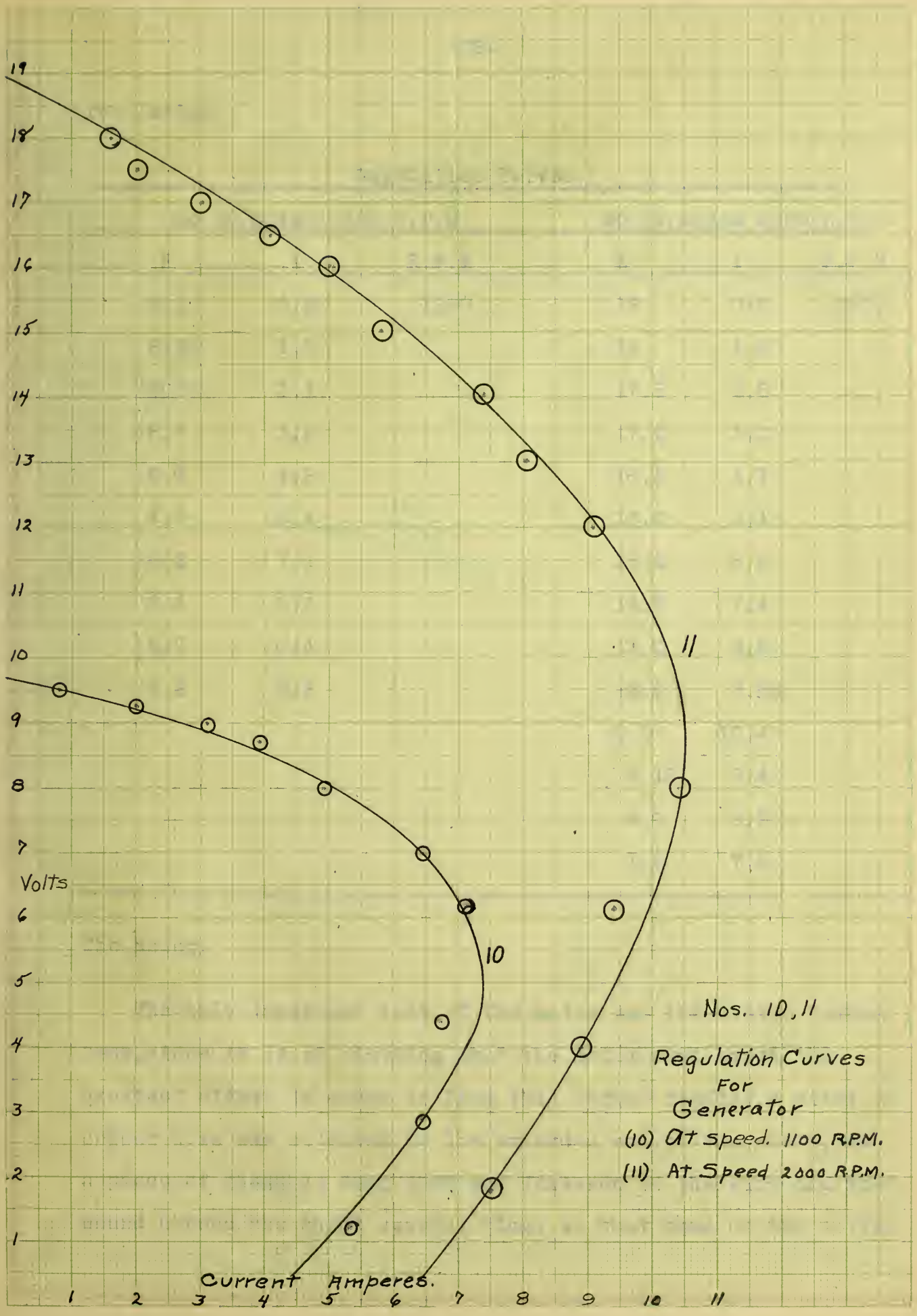
No. 9

Speed - Current and Speed - Voltage Curves Showing

Operation of Generator in charging Battery.

(a) Speed - Current.

(b) Speed - Voltage.



Nos. 10, 11

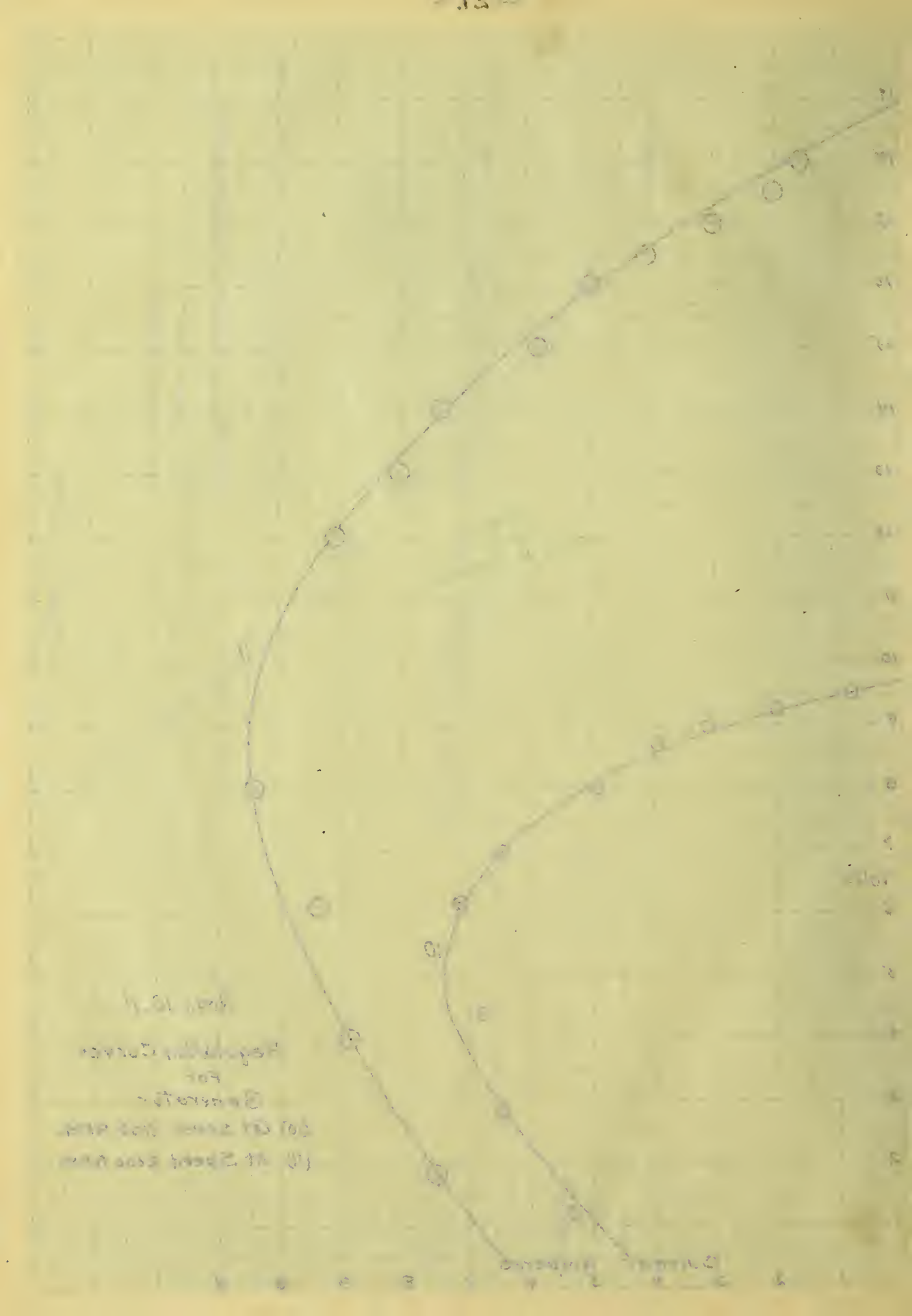
Regulation Curves

For

Generator

(10) At Speed. 1100 R.P.M.

(11) At Speed 2000 R.P.M.



regulation.

Regulation Curves.

No 10, speed 1100 R.P.M			No 11, speed 2000 R.P.M.		
E	I	R.P.M	E	I	R.P.M.
9.5	0.8	1100	19	0.0	2000
9.25	1.9		18	1.6	
9.00	3.1		17.5	2.0	
8.7	3.9		17.0	3.0	
8.0	4.9		16.5	4.1	
7.0	6.4		16.0	5.1	
6.2	7.1		15.0	5.8	
4.4	6.7		14.0	7.4	
2.9	6.4		13.0	8.0	
1.2	5.3		12.0	9.05	
			8.0	10.4	
			6.15	9.4	
			4.0	8.9	
			1.8	7.5	

The Motor.

The only important test of the motor was the static torque test, since it is at starting that the motor must exert the greatest effert. In order to find this torque readily, a piece of copper wire was soldered to the extended end of the shaft, and a piece of flexible lamp cord was fastened to the wire and then wound around the shaft several times so that none of the torque

need be exerted in bending the wire. A direct current generator was used to furnish the current. From a suspended spring balance the cord around the shaft was hung. Readings were taken of the pull for various values of the current up to 100 amperes. The current was regulated by several lamp banks in parallel (see Fig 4 The torque was calculated from the pull and the radius of the shaft plus half the diameter of the chord. Since this torque is transmitted to the engine shaft through a planetary reduction gear of 9.5 to 1 ratio and a further reduction at the flywheel of about 3 to 1 ratio, the pull at the engine shaft would be equivalent to nearly thirty times that exerted at the motor shaft. The data taken was the current values and the pull in poun pounds for each value of current. A curve was plotted for these values, (curve No12, page 24).. From the form it was seen that the torque varied as the square of the current according to the usual torque-current curve of the series motor. Therefore the curve was extended to give values of torque up to 200 amperes of current. The following diagram, Fig 4, shows the connections made for the test.

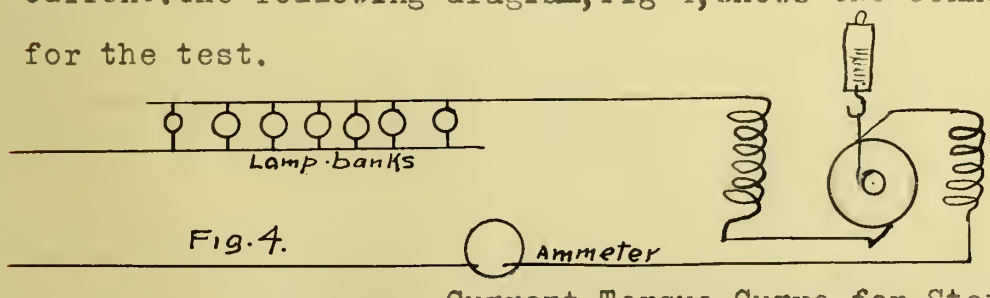
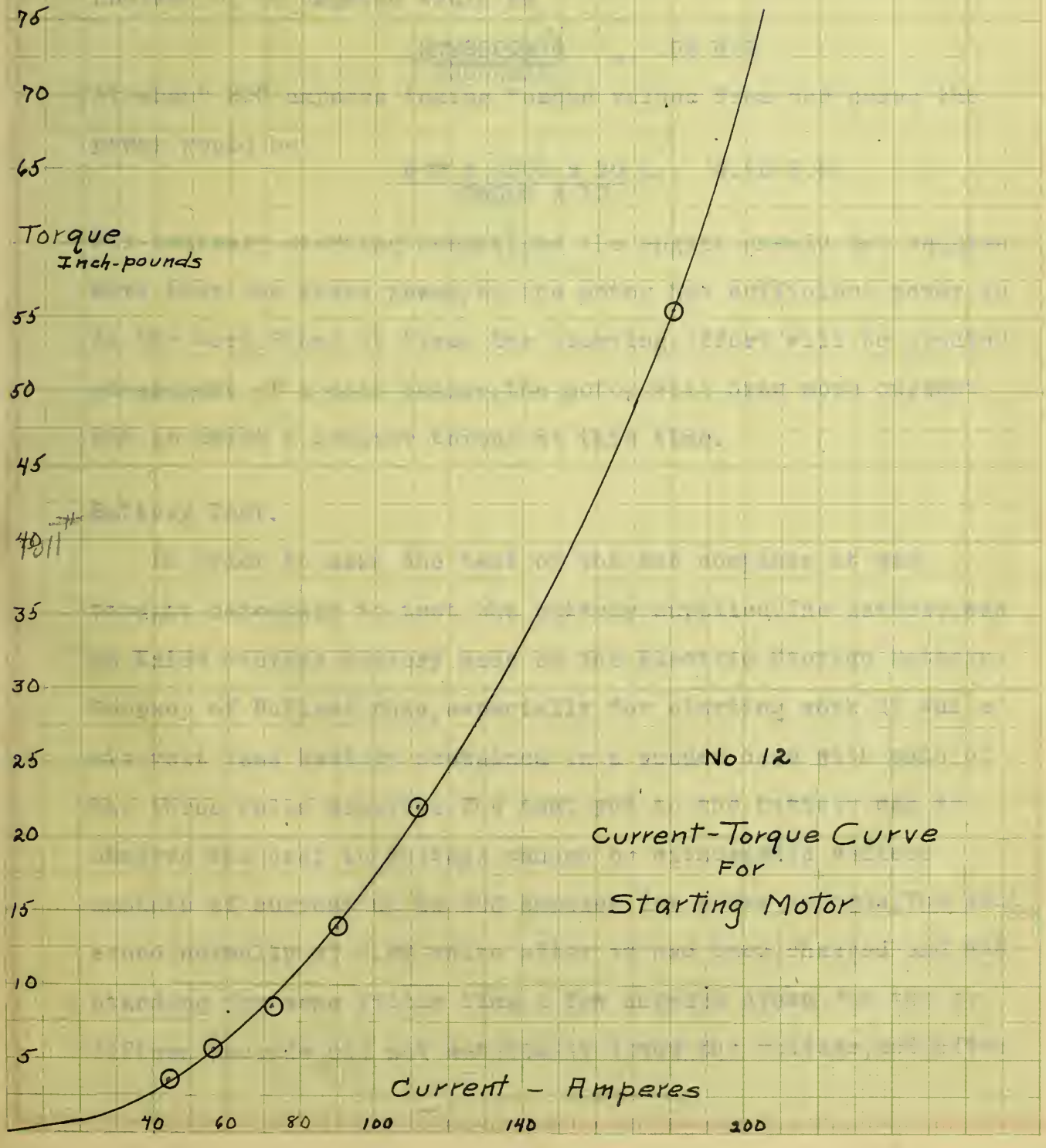


Fig. 4.

Current Torque Curve for Starting Motor

Current, amperes	Pull, lbs.	Torque inch lbs
44	7	3.5
56	11	5.5
72	17	8.5
90	28	14.0
180	112	56.0


75
70
65
Torque
Inch-pounds
55
50
45
40
35
30
25
20
15
10
5
No 12
Current-Torque Curve
For
Starting Motor
Current - Amperes
40
60
80
100
140
200

Radius of shaft equal 13/32, radius of cord equals 3/32; The lever arm then becomes 1/2 inch or 1/24 of a foot.

If we assume a cranking speed of about 100 R.P.M and a gear reduction of about 25 to 1 we will have a motor speed of about 2500 R.P.M and the horse power developed at this speed for a current of 90 amperes would be

$$\frac{2\pi \times 2500 \times 14}{33000 \times 12} = .55 \text{ H.P.}$$

At about 200 amperes taking torque values from the curve the power would be

$$\frac{2\pi \times 2500 \times 70}{33000 \times 12} = 2.75 \text{ H.P.}$$

For ordinary starting conditions the engine should not require more than one horse power, so the motor has sufficient power to do the work. Since at times the starting effort will be greater on account of a cold engine, the motor will draw more current and so exert a greater torque at this time.

Battery Test.

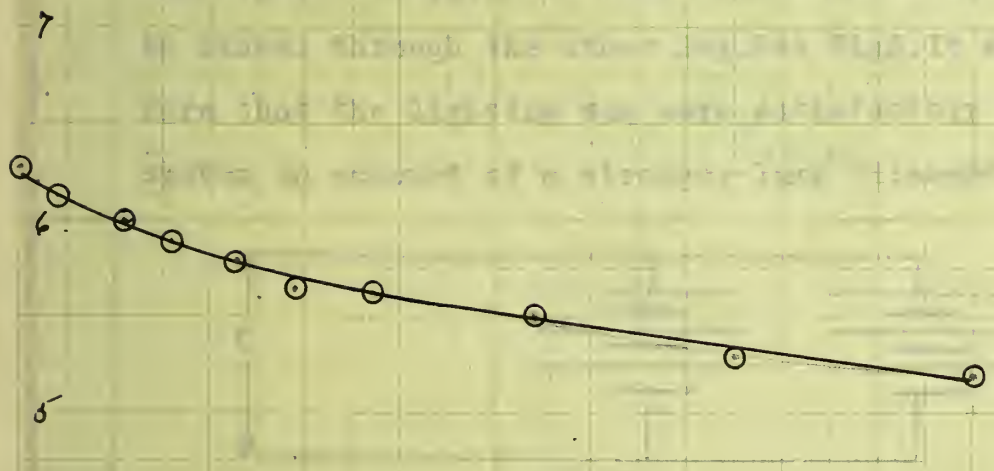
In order to make the test of the set complete it was thought necessary to test the battery supplied. The battery was an Exide storage battery made by the Electric Storage Battery Company of Philadelphia, especially for starting work. It was a six volt lead battery contained in a wooden case with each of the three cells separate. The test put to the battery was to observe the drop in voltage caused by withdrawing various amounts of current up to 200 amperes for a few seconds. The cell stood normally at 6.28 volts after it had been charged and was standing for some little time. A few amperes drawn for ten or fifteen seconds did not materially lower the voltage, but after

twenty or more amperes had been taken the drop became more noticeable.At 200 amperes the voltage had dropped to 5.2 volts. the variation is best seen from the following data and curve No 13,page 27.

Volt,Ampere Characteristic of Storage Battery on Discharge.

Current	Volts
0	6.28
8	6.14
10	6.11
22	6.0
32	5.9
46	5.8
58	5.65
74	5.62
108	5.5
150	5.3
200	5.2

It must be quite evident that the reliability of the starting device will depend on the ability of supplying current to the motor.The battery must be capable of having from 150 to 200 amperes drawn from it for a few seconds without buckling of plates.A thinner plate is sometimes used in the battery for starting purposes than for normal use in order to reduce the internal drop at this excessive discharge rate and also to reduce the weight.The heating capacity of the motor should be



Curve No. 13

Volt-Ampere Curve
For
Battery Discharge

such that it could completely discharge the battery without injury.The motor usually operate on a six volt battery,since a six volt battery can be made of sufficient capacity and lighter in weight than one of a higher voltage.The six volt battery has the further advantage of being charged in series. When parallel charging connections are used,a short circuit in one leg of the parallel connection will cause excessive current to travel through the other leg.See Fig5.It was mentioned before that the lighting was more satisfactory on the six volt system on account of a stronger lamp filament.

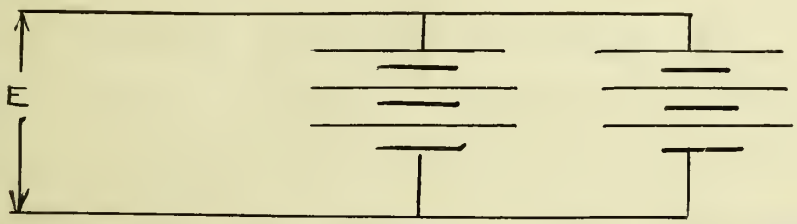


Fig. 5.

IV.

Conclusion.

The starting and lighting system of the modern gasoline automobile has been developed to a point where its operation depends mostly on the battery. The two unit system has advantages of having the machine for each duty of the best characteristics for its own operation. In the system investigated the generator is the weak part of the equipment. The theory of the design promises a good machine. It has a regulating device to avoid excessive charging current at high speeds, and is of sufficient capacity to supply the battery and also to keep up the lamp load. Its mechanical design and construction is such that little power is required from the engine for its operation. However, it must be stated that while the series coil does regulate so as to keep down the current, it is not sufficient to keep down the current at very high speeds, or to maintain an approximately constant current at varying speeds. Neither is there any method of adjustment to make the voltage different for use on cars where different speeds are required.

The motor is of the series type which has long been recognized as the best motor for good starting torque. It is capable of developing a high torque for its size and with the reduction gearing is fully able to turn any automobile engine. It is very compact and well built and seems to be a very satisfactory motor.

The control switch used is somewhat complicated and of weak construction with no method of adjustment. The coil wires are small with very low current capacity and so easily burnt out.

The battery is of good construction,high capacity and not very heavy.

The lighting and starting work done by the system has been satisfactory on many cars on which it has been used.The most prominent carson which it is installed are,Mitchell,The Kissel-Kar and the Knox.

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